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Salient nutrition labels shift peoples' attention to healthy foods and exert more influence on their choices

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ABSTRACT

Nutrition labels are the most commonly used tools to promote healthy choices. Research has shown that color-coded traffic light (TL) labels are more effective than purely numerical Guideline Daily Amount (GDA) labels at promoting healthy eating. While these effects of TL labels on food choice are hypothesized to rely on attention, how this occurs remains unknown. Based on previous eye-tracking research we hypothesized that TL labels compared to GDA labels will attract more attention, will induce shifts in attention allocation to healthy food items, and will increase the influence of attention to the labels on food choice. To test our hypotheses, we conducted an eye-tracking experiment where participants chose between healthy and unhealthy food items accompanied either by TL or GDA labels. We found that TL labels biased choices towards healthier items because their presence caused participants to allocate more attention to healthy items and less to unhealthy items. Moreover, our data indicated that TL labels were more likely to be looked at, and had a larger effect on choice, despite attracting less dwell time. These results reveal that TL labels increase healthy food choice, relative to GDA labels, by shifting attention and the effects of attention on choice.

1. Introduction

In a world with high rates of obesity accompanied by tremendous consequences and costs, understanding the mechanisms underlying food choice is crucial [1,2]. Deciding if, what, when, and how much to eat involves an interplay between the internal homeostatic balance and cognitive capacity–which encapsulates the ability to behave in line with one's goals [2,3]. Even though being healthy and living healthy seem like straightforward goals to have, research shows that the ability to behave in line with these goals seems to depend not only on interindividual differences in decision-making processes, but also on external cues that may promote different goals [4-7]. Among these external cues are nutrition labels which have become the most commonly used tool to promote healthy food choices [8].

Abbreviations: AOI, area of interest; DV, dependent variable; GDA, guideline daily amount; *M*, mean; RT, reaction time; *SE*, standard error of the estimate; *SD*, standard deviation; TL, traffic light; WTP, willingness to pay.

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While overall the presence of nutrition labels seems to have an impact on food choices, not all label formats are equally effective. Several studies have shown that compared to numerical labels (eg, monochrome Guideline of Daily Amount–GDA), labels that provide nutrition information in a more salient and easy to interpret way are more effective in helping consumers identify and choose healthier foods [9-18]. One type of salient label, which uses color codes to indicate nutrient levels, is the traffic light (TL) label. These labels have been shown to be effective in promoting healthy choice [18] but the exact mechanisms underlying their effects remain unknown.

Many studies have shown that when attended to, TL labels increase health awareness [19,20], which is an important factor associated with healthy food choice [2,5]. In line with this, Enax et al [21] showed that TL labels increase the weight on health attributes in the decision-making process. These effects of salient nutrition labels on food choice have been hypothesized to rely on attention [7, 21]. Supporting this idea, eye-tracking research has shown that while front-of-package labels attract visual attention [22], some formats attract more attention than others. More specifically, it has been shown that color coded labels, like TL labels, attract more attention than monochromatic, numerical labels [12,14,22]. Interestingly, these effects have been reported even in more naturalistic shopping environments such as canteens, where participants can see different food items with different label formats on their packaging [23]. However, what these studies do not answer is how attention more specifically relates to subsequent food choice [12,23,24].

In recent years, research has shown that attention plays an important role in the choice process, amplifying the value of attended items and attributes, and so increasing their impact on choice outcomes (for a review see [25]). These studies provide a framework for understanding how salient nutrition labels might encourage healthy food choice. The first possibility is that more salient labels simply attract more gaze, leading to more weight on nutritional information in participants' choices. A second possibility is that more salient labels divert attention away from unhealthy items towards healthy items, giving healthy items an advantage in the comparison process. Finally, a third possibility is that more salient labels more effectively convey nutrition information, thereby increasing the influence of attention paid to the label on the food choice.

The aim of this study is to explore these possibilities by examining the relationship between visual attention and food choice in the presence of different nutrition labels. Based on the findings from previous eye-tracking studies [12,25], we hypothesized that: (**H1**) more salient labels will attract more attention and will increase the weight of health in the decision process; (**H2**) more salient labels will increase the proportion of time that participants dwell on the healthier item; (**H3**) more salient labels will increase the correlation between attention and food choice. To test these hypotheses, we conducted an eye-tracking experiment where we assessed visual attention while participants performed a binary food choice task between healthy and unhealthy food items in either the presence of purely numerical labels (GDA labels) or in the presence of color-coded and thus more salient labels (TL labels).

2. Methods and materials

2.1. *Participants*

The study was conducted at the Life & Brain center in Bonn, Germany. The study was approved by the local ethics committee of the Medical Faculty of the University of Bonn, and all participants gave written informed consent according to the Declaration of Helsinki. The study protocol, and the potential risks were explained to the participants before they gave their written consent. The study was not registered at ClinicalTrial.gov. We recruited 51 participants (11 male), between the ages of 18 and 60 years old (mean [*M*] = 26.24 years old, standard deviation [*SD*] = 6.4 years old). All participants were German speakers and had either normal or corrected-to-normal vision with contact lenses on. All participants were tested for red-green deficiency to enable accurate testing during eye-tracking. Participation in the study was voluntary and participants were reimbursed with 10€ per hour and with a randomly chosen food product encountered in the experiment. One participant's data had to be excluded due to a software-malfunction. For a visualization of the criteria and the selection of the participants for the study refer to Fig. 1.

2.2. *Stimuli*

The stimulus set used in this study consisted of 100 packaged products that were chosen from the internet. All products were categorized as either healthy or unhealthy according to the TL color classification scheme label (as described in [7]). The products that were accompanied by a minimum of one green light, and no red lights were categorized as healthy. By contrast, products that were accompanied with at least one red light and at most one green light were categorized as unhealthy. We did not include products with one red and multiple green lights. The labels and values for GDA and TL were retrieved from the producer's nutrition information and the EU Food and Drink Confederation [26], as well as the Food Standards Agency's website [27], respectively. We used the same procedure as described in [21]. The label's notation and categorization were normalized to a portion size of 100 g and can be seen in Tables 1 and 2. The labels accompanying the food products were based on the products' nutrition facts and were presented below the food product (Fig. 2). The reason to separate the food images and their nutrition labels was so that we could clearly distinguish between attention paid to the nutrition labels and attention paid to the food items.

2.3. *Procedure*

Participants were asked to refrain from eating any food for 4 hours prior to the start of the experiment. The experimental procedure consisted of three parts. In the first part, participants rated each of the 100 products based on how much they

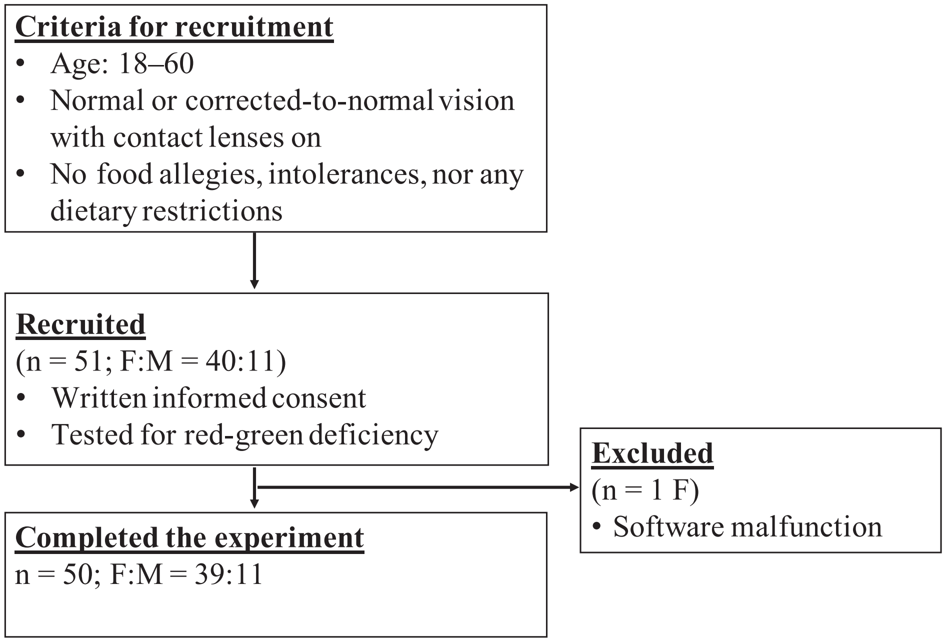

Fig. 1 – Flow diagram of the study participants from recruitment criteria to completion of the experiment. F: female; M: male.

liked their taste (subjective liking ratings) on a nine-point scale from –4 (not at all) to 4 (very much). The pictures of the products were displayed in the center of a black screen. Between each rating there was a fixation-cross that appeared for 50 ms. Participants could proceed with the task only after rating each food. In this part of the experiment, the products were shown without any nutrition labels.

In the second part of the experiment, participants had to make choices between two food products. Participants completed 480 trials in total, from which 240 were "normal" trials and 240 were trials with scrambled/unintelligible nutrition labels. The scrambled trials were included for another set of analysis for a different project. In this paper we restrict all analyses to the "normal" trials. In half of these "normal" trials, both foods were presented with GDA nutrition labels, while in the other half both foods were presented with TL nutrition labels. In total, there were five blocks of 48 trials each, and GDA/TL trials were randomly intermixed throughout these blocks. Participants indicated their choice by pressing computer keys with their corresponding index fingers. If a participant did not make a choice within 20 s, the experiment proceeded automatically to the next trial. Pictures of the two products and nutrition labels were presented on a black background (Fig. 2). To avoid possible effects of the brand information [22,28], the brand names on the products were covered up. Trials were separated by a fixation cross shown on a black background for 1000 ms.

In the third and final part of the experiment we assessed participants' willingness to pay (WTP) for each product. To do so, participants were asked to indicate the price they would pay for each food if they saw it in a supermarket. Like in the first part of the experiment, in this task the food products were presented in the middle of a black screen without any nutrition label. We ended up not using these WTP ratings in our analyses because they were potentially contaminated by the earlier choice trials; for a discussion on these issues see [29].

In addition to these measurements, we also assessed participants' weight, height, waist to hip ratio, and their attitudes towards eating behavior (assessed *via* questionnaires). These measures were acquired as part of a different project and are not included in our analysis.

All parts, except the questionnaires and the assessment of the anthropometric variables, were computer-based. However,

Table 1 – Guideline daily amount for an average adult

Ingredient	Value	Example values per 100 g	
Caloric requirement	2000 kcal	334 kcal	17% of GDA
Sugar	90 g	1.5 g	2% of GDA
Fat	70 g	2.0 g	3% of GDA
Saturated fatty acids	20 g	0.4 g	2% of GDA
Sodium	2.4 g	0.3 g	13% of GDA

GDA, guideline daily amount; g, gram; kcal, kilocalorie. In the GDA labels values for a portion of 100 g are displayed.

Table 2 – Guidelines for traffic light labels

Ingredient	Green (low content)	Yellow (middle content)	Red (high content)
Sugar	<5 g	5-12.5 g	>12.5 g
Fat	<3 g	3-20 g	>20 g
Saturated fatty acid	<1.5 g	1.5-5 g	>5 g
Sodium	<0.12 g	0.12-0.7 g	>0.7 g

The values are calculated for a portion size of 100 g. Color coding does not apply to energy information.

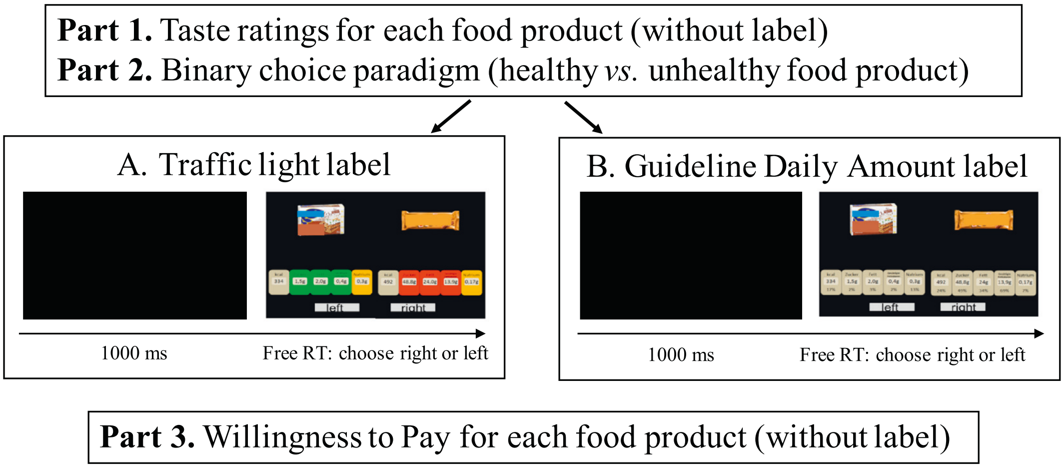

Fig. 2 – Experimental paradigm. **In the first part participants had to rate every food item in terms of how much they liked the taste of that food item. In the second part participants had to make a binary food choice between a healthy and an unhealthy item. This task consisted of trials where the food products were shown with a TL label (TL trials) and trials where the food products were shown with a GDA label (GDA trials). The brand names were covered up. In the third part participants were asked to indicate how much they were willing to pay for every food product. GDA: guideline daily amount; TL: traffic light; RT: reaction time.**

we collected eye-tracking data only in the second part (binary choice task). For this, we used the EyeLink 1000 (SR research Ltd, Mississauga, Ontario, Canada) eye-tracker with a sampling rate of 1000 Hz, and average accuracy lower than 0.5°. Calibration was done using a standard 13-point calibration task provided by the manufacturer (white dots, black background). Participants were seated at an approximately 50–55 centimeter distance from the EyeLink camera, which was positioned centrally and immediately under the 27 × 35-cm screen. Their head was placed on a forehead- and chin rest (the "tower"), to stabilize the participants and avoid movement during testing. The settings were adjusted to each participant, regarding the cornea-reflex, calibration and validation. Following every 20th trial, the eye tracker was recalibrated to ensure accurate measurement. The food rating, food choice, and WTP tasks were created and displayed using Experiment Builder software (SR Research Ltd., version 2.1.140).

Because we were interested in the attention paid to the food items, and the attention paid to the labels, our areas of interest (AOI) included the images of the food items, and the nutrition labels (see **Supplemental Fig. S1**). We analyzed the individual dwell times and the total dwell times on the food items (*item dwell time*, *total item dwell time*) and on the nutrition labels (*label dwell time*, *total label dwell time*). Individual dwell times refer to the amount of time spent looking at an AOI before moving on to another AOI, whereas total dwell times refer to the amount of time spent looking at a given AOI over the course of the whole trial.

2.4. *Statistical analyses*

Statistical analysis was performed using R (version 3.6.1) [30] and R Studio (version 1.2.1335) [31]. The following packages were used: *lme4* (version 1.1–21), *lmerTest* (version 3.1–0), *ggplot2* (version 3.2.1), *plyr* (version 1.8.4), *grid* (version 3.6.1). The data was analyzed using full mixed-effects regressions (either linear or logistic, depending on the type of the dependent variable) to account for repeated measures within subjects. In cases where these mixed-effects models did not successfully converge, we report the results from regression models with clustered standard errors (cluster-corrected models). Additionally, paired *t*-tests were used to compare mean percentages, and Pearson correlation analysis was used to test for associations between the time participants spent looking at the labels and the probability of choosing healthy items. Variables that were not normally distributed, were log transformed. The detailed analyses of the behavioral and eye-tracking data are explained below.

2.4.1. *Behavioral data analyses*

Using the behavioral data, we first sought to replicate previous findings on the effect of subjective liking ratings on reaction times (RTs) and choice, and further investigate whether these effects depend on the type of the label with which the food items were presented (either TL or GDA). Second, we sought to establish the effect of TL labels on choosing the healthier food items. For these analyses we estimated mixed-effects regression models, and alternatively cluster-corrected regression models, where our behavioral dependent variables (*RTs, left choice*, *healthy choice*) were regressed against the difference in subjective rating between the two food items shown in a pair, interacted with the *TL label* dummy (1 = Yes, 0 = No).

2.4.2. *Eye-tracking data analyses*

Similar to the behavioral data, with the eye-tracking data, we first aimed to replicate previous findings on the relation between attention, value, and choice, and further investigate whether these relations change depending on the label format with which the food items were presented.

Second, we assessed whether TL labels attract more attention (**H1**), and whether their presence causes differences in attention allocation to the food items (**H2**). To do this, we regressed attention measures (*item dwell time*, *label dwell time*) against type of item/label (healthy 1 = Yes, 0 = No), and *item rating difference,* both interacted with *TL label* (1 = Yes, 0 = No).

Third, to test our **H3** hypothesis we assessed whether the relative contribution of attention (paid to the labels, paid to the food items) and subjective liking ratings on making a healthy food choice was different with TL labels. For this we estimated regression models with *healthy choice* (1 = Yes, 0 = No) as the dependent variable, and *item rating difference* (rating of the healthy food item– rating of the unhealthy food item), *total item dwell time difference* (total time spent looking at the healthy food item–total time spent looking at the unhealthy food item), *total label dwell time difference* (total time spent looking at the healthy label–total time spent looking at unhealthy label), all interacted with *TL label* (1 = Yes, 0 = No) as fixed effects. Finally, to capture these effects at the subject level, we examined the across-subject correlations between the average fraction of dwell time on the labels and the probability of choosing healthy items.

3. Results

In summary, we first show the behavioral effect of subjective liking ratings on food choice and RTs, and the effect of nutrition labels on making healthy food choices. Second, we show the effect of nutrition labels on the relation between gaze, value, and choice. Third, we show the effect of nutrition labels on attention allocation (**H1** and **H2**) and how this relates to food choice (**H3**).

3.1. *Behavioral data results*

To establish that participants' choices are responsive to their subjective liking ratings, we regressed *left choice* (1 = Yes, 0 = No), on *item rating difference* (rating of the food item on the left – rating of the food item on the right), *TL label* (1 = Yes, 0 = No), and their interaction. This mixed-effects logistic regression indicated that *item rating difference* significantly predicted food choice ($\beta = 0.54$, $z = 12.94$, $P < 10^{-16}$). However, there was a significant negative interaction between *TL label* and *item rating difference*, indicating that taste ratings were significantly less predictive of choice in the TL trials compared to the GDA trials ($\beta = -0.07$, $z = -1.98$, $P = .047$).

To assess whether TL labels increased the bias for choosing the healthier item, we performed cluster-corrected logistic regression with *healthy choice* (1 = Yes, 0 = No) as the dependent variable, *TL label* (1 = Yes, 0 = No), *item rating difference* (rating of the healthy food item – rating of the unhealthy food item), and their interaction as fixed effects. This analysis revealed a significant positive intercept ($\beta = 0.26$, $z = 2.25$, $P = .025$), which indicates a bias to choose the healthy item on GDA trials with a rating difference of zero (when the two items were liked same). The *TL label* coefficient was also significantly positive ($\beta = 0.40$, $z = 4.06$, $P = 10^{-5}$), indicating an increased bias to choose healthy food items when presented with TL labels. Interestingly, there was no significant interaction effect between *TL label* and *item rating difference* ($\beta = -0.017$, $z = -0.50$, $P = .62$), suggesting that subjective liking ratings had a similar effect on healthy choice in both the TL and the GDA trials (see Fig. 3a). When not controlling for subjective liking ratings, the bias to choose healthy was significant only in the presence of TL labels (Mixed-effects logistic regression results: $\beta_{\text{TL label}} = 0.3$, $z = 3.18$, $P = .001$; $\beta_{\text{intercept}} = -0.04$, $z = -0.37$, $P = .71$).

To assess whether participants were faster in the easy trials (trials that involved food items with larger difference in subjective ratings) and whether this was dependent on the type of the labels that were presented, we ran a mixed-effects regression with *log(RT)* as the dependent variable, *absolute item rating difference*, *TL label* (1 = Yes, 0 = No), and their interaction as fixed effects. This analysis revealed that, as seen in previous work, there was a significant negative effect of the *absolute item rating difference* on RTs ($\beta = -0.06$, $t = -9.12$, $P = 10^{-10}$), which means that easier choices were made significantly faster. The effect of *TL label* was also significant ($\beta = -0.052$, $z = -2.49$, $P = .016$), indicating that in the TL trials participants were significantly faster for a rating difference of zero. A significant interaction between *absolute item rating difference* and *TL label*, indicated that the effect of the liking ratings on RTs was reduced for the TL-labeled food items ($\beta = 0.013$, $t = 2.256$, $P = .031$). This suggests that taste was having less of an effect on the decision process in the presence of TL labels.

Looking again at RTs, one can see that the inverse-U-shaped curve, as a function of item rating difference, is shifted to the left for the TL trials (Fig. 3b). The peaks of these curves reveal participants' indifference points [32]. For the GDA labels the peak of the curve occurred at −1, indicating that the healthy item essentially gained 1 rating point for its healthiness. For the TL labels the peak occurred at −2 instead, doubling the advantage for the healthy item compared to the health advantage with GDA labels.

3.2. *Eye-tracking data results*

3.2.1. *Relationship between value, attention, and choice*

Our data indicated that as seen in previous studies [25], there was no tendency for participants to look at higher-rated food items first, nor was there a tendency to look at them longer. However, there was a tendency to choose the food items that were looked at last. These effects did not depend on the TL label (see **Supplemental Tables S1, S2 and S3** and **Supplemental Fig. S2**). Similarly, there was a significant tendency to choose the food items that were looked at more, independent of the label. Interestingly, while there was a tendency to choose the food items whose labels were looked at more, this effect was stronger in the presence of TL labels (see **Supplemental Table S4** and **Supplemental Fig. S3**).

3.2.2. *The effect of nutrition labels on attention (H1 & H2)*

To test our **H1** and **H2** hypotheses, we assessed the effect of TL label on the total dwells and on the individual dwells. Below we report the results on the individual dwells (excluding the final dwell in each trial), whereas the results on the total dwell times can be seen in **Supplemental Table S5** and **Supplemental Fig. S4**.

To test our **H1** hypothesis, we first counted the trials where the labels were looked at and the trials where labels were not looked at. Paired *t*-tests indicated that participants were more likely to look at TL labels compared to GDA labels (see **Supplemental Fig. S5**). More specifically, they did not look at

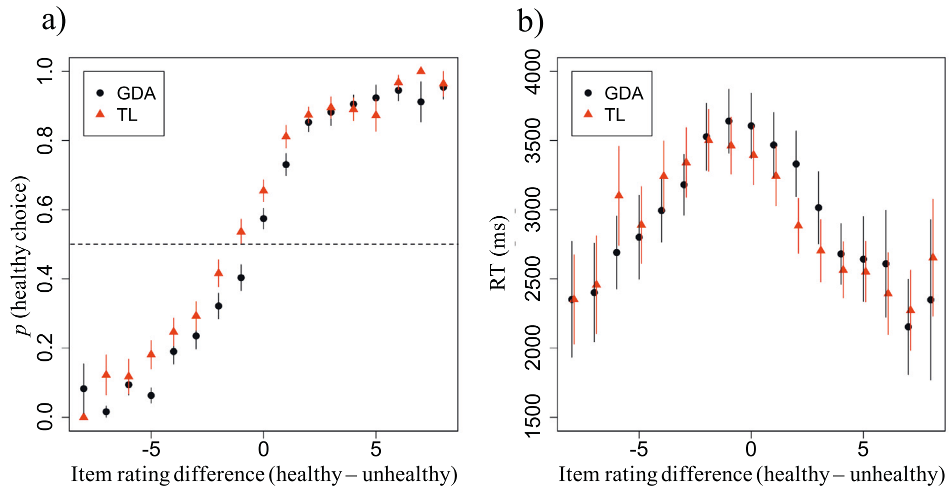

Fig. 3 – Effect of labels and subjective liking ratings on choices (a) and RTs (b). Data points are mean values with standard errors clustered by subject (*n* = 50). (a) Participants generally chose in line with their subjective liking ratings, choosing the healthier item when it was rated higher than the unhealthy item, and *vice-versa*. Across the rating-difference bins participants were consistently more likely to choose the healthy item with the TL labels and showed a healthy-choice bias of ~15% when otherwise indifferent between the items ($\beta_{TL\ label}$ = 0.40, *z* = 4.06, *P* = 10^{-5}). Effects are estimated using cluster-corrected logistic regression analyses. (b) Participants' indifference points were different for the two trial types. While for the GDA trials this point was at –1, for the TL trials this was at –2; indicating a doubled bias in favor of the healthy item in the TL trials compared to the GDA trials. GDA: guideline daily amount; TL: traffic light; RT: reaction time.

both labels (because they looked at no labels or they looked at only one label) in 54% of the GDA trials *vs.* 50% of the TL trials ($t_{(49)}$ = 2.31, *P* = .025), and looked at no labels in 43% of the GDA *vs.* 38% of TL trials ($t_{(49)}$ = 3.86, *P* = .0003). In the trials where participants did not look at the labels, RTs were significantly shorter (*M* = 1.71 s, *SD* = 1.01 s) than in the trials where the labels were looked at (*M* = 4.2 s, *SD* = 2.09 s; mixed-effects regression results: $\beta_{label\ looked\ at}$ = 0.73, t = 18.77, *P* < .0001). Additionally, in the trials where the labels were not looked at, there was a larger absolute item rating difference (see **Supplemental Fig. S6**). These findings suggest that participants generally relied first on the item ratings and only in close situations turned to the nutrition labels.

When considering the individual dwells to the labels, we saw that on average participants looked at TL labels (*M* = 412 ms, *SD* = 168 ms) less than GDA labels (*M* = 506 ms, *SD* = 199 ms). To assess whether these differences depended on the healthiness of the label (healthy label *vs.* unhealthy label), we regressed individual dwells to the labels (*log[label dwell time]*) on the healthiness of the label (*healthy label*, 1 = Yes, 0 = No), *TL label* (1 = Yes, 0 = No) and their interaction. These mixed-effects regression analyses indicated that there was no significant effect of the healthiness of the label (*β* = –0.023, *z* = –7.43, *P* = .16); this means that in the GDA trials there was no significant difference in dwell time between healthy and unhealthy labels (GDA unhealthy labels: *M* = 504 ms, *SD* = 214 ms; GDA healthy labels: *M* = 522 ms, *SD* = 208 ms). On the other hand, the effect of *TL label* was significant (*β* = –0.24, *z* = –7.54, *P* = 10^{-9}), indicating that participants spent less time looking at unhealthy TL labels. The same model revealed no significant interaction between *TL label* and *healthy label*, indicating no difference between healthy and unhealthy TL labels (*β* = 0.0006, *z* = 0.028, *P* = .98; TL-labeled unhealthy labels: *M* = 417 ms, *SD* = 183 ms; TL-labeled healthy labels: *M* = 410 ms, *SD* = 156 ms) (Fig. 4). An additional model with regressors for *current item rating*, *other item rating*, and *absolute item rating difference* yielded very similar results (see **Supplemental Table S6**).

When looking at the individual dwells to the food items, we saw that on average participants spent less time looking at the unhealthy food items (*M* = 512 ms, *SD* = 137 ms), than healthy food items (*M* = 523 ms, *SD* = 142 ms). To assess whether these differences depend on the presence of TL label (as stated in our **H2** hypothesis), we regressed the individual dwells to the food items (*log[item dwell item]*) on the healthiness of the food item (*healthy food*, 1 = Yes, 0 = No), *TL label* (1 = Yes, 0 = No) and their interaction. Mixed-effects regression analyses revealed a non-significant effect of the healthiness of the food item on the *log(item dwell time)* (*β* = 0.0085, *z* = 0.68, *P* = .5). This indicates that in the GDA trials, there was no significant difference between how much participants looked at the healthy *vs.* unhealthy food items (GDA labeled healthy items: *M* = 519 ms, *SD* = 145 ms; GDA labeled unhealthy items: *M* = 520 ms, *SD* = 143 ms). The same analyses revealed that the effect of *TL label* was significant, indicating that in the TL trials, participants spent less time looking at the unhealthy food items (*β* = –0.033, *z* = –2.58, *P* = .01). There was a significant interaction between *TL label* and *healthy food* (*β* = 0.047, *z* = 2.77, *P* = .008; TL-labeled healthy items: *M* = 526 ms, *SD* = 143 ms; TL-labeled unhealthy items: *M* = 504 ms, *SD* = 135 ms) (see Fig. 4). An additional model with regressors for *current item rating*, *other item rating*, and *absolute item rating difference*, yielded very similar results (see **Supplemental Table S6**). Altogether, these results indicate that in the presence of TL labels, participants dwelled less on the unhealthy items.

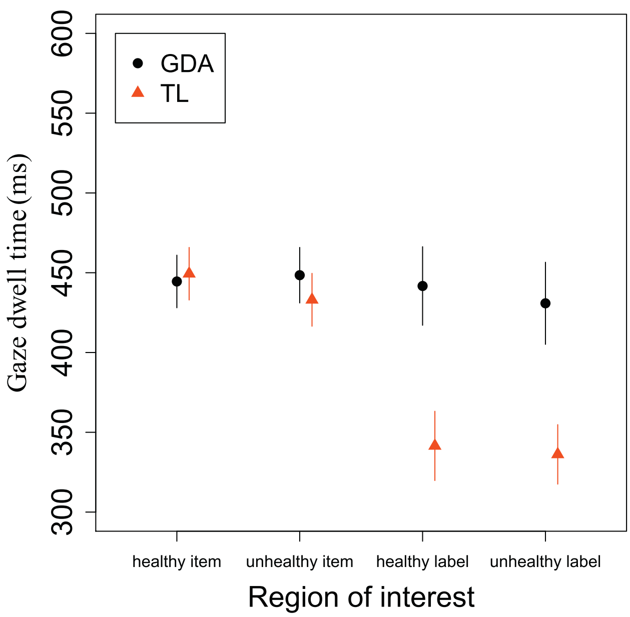

Fig. 4 – Effects of nutrition labels on the attention paid to the food items and the labels. Data points represent median individual gaze dwell times with standard errors clustered by subject (*n* = 50). In this figure the final fixation of each trial is excluded. Participants spent significantly more time looking at the healthy food items in the TL trials ($\beta_{TL\ label\ x\ healthy\ food}$ = 0.047, z = 2.77, P = .008). Similarly, participants spent substantially less time looking at the TL labels relative to the GDA labels ($\beta_{TL\ label}$ = –0.24, z = –7.54, P = 10^{-9}). Effects are estimated using mixed-effects regression analyses. GDA: guideline daily amount; TL: traffic light.

Table 3 – Relative contribution of subjective value and attention on the probability of making a healthy choice

DV: Healthy choice (1 = Yes, 0 = No)	*Estimate (SE)*	*Estimate (SE)*
Intercept	**0.25** *(0.12)**	–0.13 *(0.13)*
TL label	**0.35** *(0.10)****	0.15 *(0.11)*
Item rating difference	**0.51** *(0.03)****	**0.52** *(0.03)****
Total item dwell time difference	**1.40** *(0.13)****	**1.38** *(0.14)****
Total label dwell time difference	**0.71** *(0.19)****	**0.48** *(0.14)****
Look at healthy label		**1.95** *(0.33)****
Look at unhealthy label		**–1.20** *(0.33)****
TL label × Item rating difference	**–0.037** *(0.03)****	–0.01 *(0.04)*
TL label × Total item dwell time difference	**–0.32** *(0.14)**	**–0.36** *(0.15)**
TL label × Total label dwell time difference	**0.42** *(0.19)**	**0.38** *(0.18)**
TL label × Look at healthy label		0.11 *(0.28)*
TL label × Look at unhealthy label		0.27 *(0.31)*

DV, dependent variable; *SE*, standard error of the estimate; TL, traffic light.
Values represent estimates with their corresponding standard errors (*n* = 50). The estimates were calculated using logistic regression with cluster corrected standard errors. Significant effects are presented in bold. Significance is assessed using z-test of coefficients. Differences in ratings are calculated by subtracting the rating of the unhealthy food item from the rating of the healthy food item. Similarly, dwell time differences are calculated by subtracting the time spent looking at the unhealthy food item/label, from the time spent looking at the healthy food item/label. ***P < .001, *P < .05.

3.2.3. *The effect of nutrition labels on the relation between attention and healthy food choice (H3)*

To test our **H3** hypothesis, and to tease apart the effect of attention paid to the items, attention paid to the labels, and subjective liking ratings on food choice, we regressed *healthy choice* (1 = Yes, 0 = No) on *total item dwell time difference* (total time spent looking at the healthy food item – total time spent looking at the unhealthy food item), *total label dwell time difference* (time spent looking at the healthy label – time spent looking at the unhealthy label), *item rating difference* (rating of the healthy food item – rating of the unhealthy food item), *TL label* (1 = Yes, 0 = No), and its interaction with the other variables. This cluster-corrected regression analyses revealed that there was a significant bias for choosing the healthy item, as indicated by a significant positive intercept (*β* = 0.25, z = 2.13, P = .03). A significant effect of *TL label* indicated that this bias was higher in the presence of TL labels (*β* = 0.35, z = 3.44, P = .0006; for the full model results see Table 3). The interaction between *TL label* and *total item dwell time difference* was significant (*β* = –0.32, z = –2.23, P = .026), indicating that in the presence of TL labels the effect of dwell time on food choice is reduced. The interaction between *TL label* and *total label dwell time difference* was also significant (*β* = 0.42, z = 2.17, P = .03), indicating that TL labels increase the effect of dwell time on the labels on choice. Looking at the correlation between fraction dwell time on the labels and the probability of making a healthy choice also supports this finding (Fig. 5). The effect of *TL label*, and its interaction with *total item dwell time difference* was still significant even when controlling for the last fixation location (see **Supplemental Table S7**).

To check whether the effect of TL labels on healthy food choice might come solely from them being more likely to be seen, we ran the same regression analysis as above, with additional dummy variables for whether a nutrition label was looked at or not. More specifically, we included *healthy label looked at* (1 = Yes, 0 = No), and *unhealthy label looked at* (1 = Yes, 0 = No), in addition to the attention measures and subjective liking ratings. This analysis indicated that indeed, when accounting for whether a label is looked at or not, the effect of *TL label* was no longer significant (*β* = 0.15, z = 1.38, P = .17). However, the interaction between *TL label* and *total label dwell time difference* (*β* = 0.38, z = 2.14, P = .03), as well the interaction between *TL label* and *total item dwell difference* (*β* = –0.36, z = –2.43, P = .02) were again significant (for the full model results see Table 3). Overall, these analyses reveal that TL labels exert their influence by increasing the effect of attention to labels and decreasing the effect of attention to foods, on choice. Furthermore, in this study, we did not observe any differences between males and females in how much they looked at the labels or how much they were influenced by the labels in their choices (**Supplemental Fig. S7** and **Supplemental Table S8**).

4. Discussion

In this study, we aimed to assess possible mechanisms of how TL labels encourage healthy food choice. We found that TL

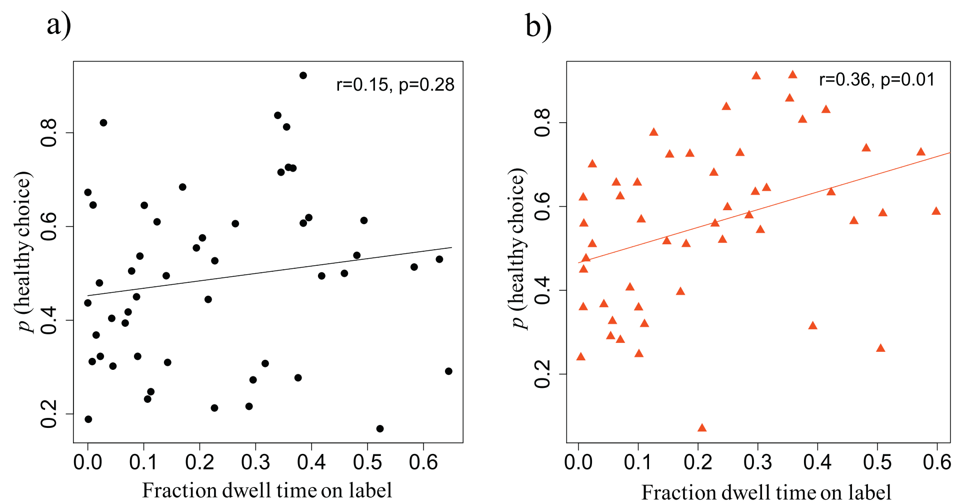

Fig. 5 – Probability of making a healthy choice as a function of the fraction dwell time on the (a) GDA and (b) TL nutrition labels. Each dot is the data from one participant (n = 50). Pearson correlation analyses were used to assess the strength of the correlations. GDA: guideline daily amount; TL: traffic light.

labels induce more attention to healthy food products and increase the choice effect of attention paid to the labels while decreasing the choice effect of attention paid to the foods. These findings support our **H2** and **H3** hypotheses. Surprisingly, our results do not support the hypothesis that TL labels will attract more gaze (**H1**); to the contrary they suggest that even though TL labels are more likely to be looked at, they attract shorter dwells.

As shown in previous studies, we find that participants' food choices are explained by subjective ratings of taste [2,21,33]. Interestingly, when considering the labels with which the food items were presented, we find that the effect of subjective ratings on food choice is significantly reduced when the items are presented with the TL labels compared to GDA labels. While decreasing the effects of subjective liking ratings and decreasing the RTs, the presence of TL labels induced a significantly higher bias to choose the healthier food item compared with GDA labels. This is in line with previous studies that have shown that salient labels increase the frequency of healthy choices in the lab [11,12,21], and also increase the sales of healthy food products in different populations [15,19,34].

As hypothesized before [21], our results show that indeed, salient labels induce shifts in attention allocation. More specifically, we found that in the presence of TL labels, participants looked at healthy items significantly more than at the unhealthy items, while this difference was not apparent in the presence of GDA labels. This shift in attention allocation was associated with an increased bias to choose healthy in the TL trials but not in the GDA trials. Together these findings support the hypothesis that in the presence of TL labels, healthy food items get an advantage in the evidence gathering and value comparison process.

In addition to the effects of nutrition labels on the attention paid to the food items, the presence of the labels attracts attention to the nutrition information related to the respective foods. In line with previous studies, our results support that TL labels are more likely to be looked at, possibly due to their physical features, including colors in addition to numerical information [22,35]. However, even though they were more likely to be looked at, compared to the GDA labels TL labels attracted less dwell time overall. Even though attending to a stimulus indicates that participants are gathering evidence on that particular option, it does not necessarily mean that this gathered evidence is utilized correctly in the value computation processes. It could just as well reflect the fact that due to their numeric features, extracting information from the GDA labels requires more cognitive effort [36,37]. Indeed, when looking at how attention paid to the labels relates to choice, we found that in the GDA trials the attention paid to the label and the attention paid to the food item had a similar effect on the food choice. On the other hand, in the TL trials, the attention paid to the label had a higher impact on the food choice, compared to the attention paid to the food item. This indicates that the effect of the TL labels was to boost the effect of dwell time on the labels but shrink the effect of dwell time on the items. Furthermore, when looking at across-subject correlations between the dwell time on the label and the probability of making a healthy choice, we saw that for the TL labels this correlation was stronger than for the GDA labels, supporting the idea that the information acquired from the TL labels influenced the choices more.

Interestingly, when accounting for whether a label was looked at all, in addition to the other attention measures (item and label dwell times), and the subjective liking ratings, the main effect of the TL labels on the probability of choosing healthy disappeared, but the significant interactions of TL label with label dwell time and item dwell time remained. Altogether, these results suggest that TL labels operate by increasing the likelihood of the nutrition information to be looked at, by increasing the effect of dwell times on the labels, and by decreasing the effect of dwell times on the items.

There are some limitations to the present study. First, in this study, the nutrition labels were shown separately from the food items (below) and were larger than the ones usually found in packaging. We designed the study this way so that we could clearly distinguish between the consideration given to the food items and labels. While this presentation resembles online shopping using digital displays/touchscreens where nutrition labels can be magnified, it may not completely reflect the allocation of attention to food items and nutrition labels in brick-and-mortar shops. In these shopping environments, nutrition labels are smaller and are located on the actual packaging of the food products—which can make them less salient. While this might cause one to question whether TL labels would have the same effect in the field, we do know that lab experiments using more realistic stimuli also provide evidence that color-coded labels are more effective than purely numerical labels in promoting healthy food choices [12,16]. It is possible that by increasing the size of the labels in our study we may have in fact underestimated the advantage of TL labels over GDA labels, since TL labels have the advantage of standing out on the package and also being easier to decipher for those who have trouble reading small print. Thus, TL labels may have an even bigger advantage in brick-and-mortar shops. On the one hand, there is indeed evidence from field studies that these color-coded labels are effective [10,13,15,19,20,34]. On the other hand, bigger nutrition labels would be more salient [35], and likely more effective. Increasing the size of nutrition labels is thus an interesting direction to pursue in future research. To further increase the generalizability of these findings, future studies might also consider investigating these effects when combining eye-tracking with virtual reality setups, which might produce a more realistic shopping environment [38].

Second, since the aim of the study was to investigate the effects of TL labels on attention, the two label formats were not pitted against each other in any trials; participants had to always choose between food items with the same label format. There were no choices between a food item with a TL label and a food item with a GDA label. It would be interesting to know how subjects treat a GDA labeled food when compared directly against a TL-labeled food.

Third, by design, in this study the food items shown in a pair included one healthy (no red lights, and minimum one green light), and one unhealthy (minimum one red light, maximum one green light) item. We did not use a continuous measure of the healthiness difference between the food products in a pair. Future work could additionally try to model how attention and label type interact with the relative degree of healthiness, rather than using our rough healthy *vs.* unhealthy dichotomy. On a similar note, while we included a semi-continuous WTP task to assess participants' preferences for the presented food items, we did not use this measure in our analyses as it was likely contaminated by the preceding binary food choice task [29]. This aspect of the design makes it difficult to investigate the downstream effects of nutrition labels on WTP. While this was not the aim of our study, future research aspiring to study such influences should avoid eliciting WTP after a choice task.

Fourth, while our sample consisted of both male and females, the number of female participants was much higher (n = 39) than that of the male participants (n = 11). This could be important to note especially since previous studies have shown that there are differences between males and females in how much nutrition labels are considered when making food choices [8,39,40]. In this study, we did not observe any differences between males and females in how much they looked at the labels or how much they were influenced by the labels in their choices as presented in the results. However, these results should be considered with caution, given the small number of male participants. In particular, our various coefficient estimates are likely closer to the female values than to the male values, if there are differences between them. To assess possible gender differences, future studies should consider recruiting similar numbers of male and female participants.

Last, while we assessed participants' subjective ratings of the food products used in the binary choice task, we did not assess several other factors that could have influenced their food choice behavior and their attitude towards the nutrition labels, including participants' individual characteristics, as well as interindividual differences in self-control, and eating styles [41-44]. These are interesting avenues for future research.

Overall, our findings provide novel insights on the mechanisms underlying the effect of nutrition labels on food choice, which have practical implications. The usage of nutrition labels is among the most promising public policy strategies to promote healthy choices [8,33]. Advancing knowledge about how these labels influence food choices will hopefully lead to more efficient labels. In this context, our study supports the use of more salient labels instead of purely numerical labels, since they are more likely to be looked at, increase the use of the nutritional information provided on the label, and consequently affect food choice.

Supplemental materials

Supplemental materials to this article can be found online at https://doi.org/10.1016/j.nutres.2020.06.013.

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